INFUSION

Innovations from the NASA CICT Program

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Computing, Information, and Communications Technology Program

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Transmitting Data from Space at Higher Speeds

- **High-power traveling wave tube (TWT) targeted at Mars and Jupiter missions**
- **100W output will speed data transfer**
- **Ka-band link will increase RF spectral range to Deep Space Network**

As NASA moves deeper into space, data communications become increasingly important because of the vast transmission distances and the growing dependency on a wide range of remote devices, such as planetary orbiting satellites.

The CICT Program's Space Communications (SC) Project is responsible for developing technologies that deliver data quickly between Earth and space, and directly to users. To achieve this ambitious goal, the SC Project is providing technologies for building the Space Internet, which will require backbone networks that pass data from one infrastructure to another. These infrastructures include the Earth-based wide-area and local-area networks, NASA's Tracking and Data Relay Satellite System (TDRSS) that provides links between Low Earth Orbit (LEO) spacecraft and the ground, planetary networks, and the Deep Space Network (DSN).

As part of this effort, the SC Project's Backbone Networks group is developing new, high-power microwave sources, including a new Ka-band, 100W high-power traveling wave tube (TWT) that will provide high-rate, high-capacity, direct-to-Earth, return links for science data and video from planetary orbiters, such as those destined for Mars.

How a traveling wave tube works

A traveling wave tube is essentially a voltage amplifier—a specialized vacuum tube that can generate or amplify microwave signals (see illustration of the 100W Traveling Wave Tube on next page). It has an electron gun at one end that fires a focused beam of high-energy electrons through the axis of the helix (or delay line) and into the "collector" at the other end of the tube. The RF signal traveling along the helix coil is amplified by the beam of electrons passing through the axis of the helix.

The electron gun

The electron gun converts the electrical energy from the onboard power supply into kinetic energy in the form of an electron beam. The gun consists of a filament, a cathode, and two electrodes. The energized filament heats the cathode to a specified temperature of 930-1,000˚C, causing it to emit electrons. The first electrode

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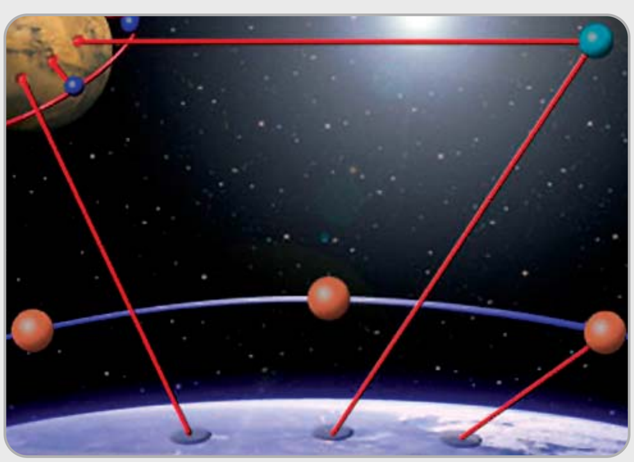

The Ka-band, 100W high-power traveling wave tube will be a key element in the Space Communications Project's high-rate backbone network (left), which will pass data from different infrastructures of the Space Internet.

Technology Spotlight

Technology

100-watt high-power traveling wave tube

Function

Amplifies electromagnetic communication waves at radio and microwave frequencies to provide high-rate transmission of data and video between Earth and space

Relevant Missions

- U.S. Mars Telesat (2009)
- JIMO—Jupiter Icy Moons Orbiter (2011 or later)
- Other Exploration Systems Enterprise missions

Applications

- Planetary orbiters
- Data-relay satellites
- Inner planet remote-sensor/orbiters that use solar power

Benefits

- Delivers approximately 60% overall efficiency
- Boosts TWT output power from 10W (Cassini satellite) to 100+W
- Covers broader RF spectral range
- Provides better performance than X-band TWTs

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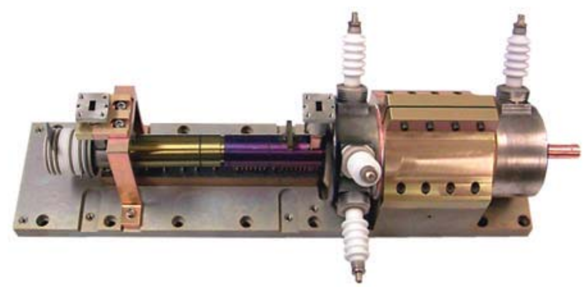

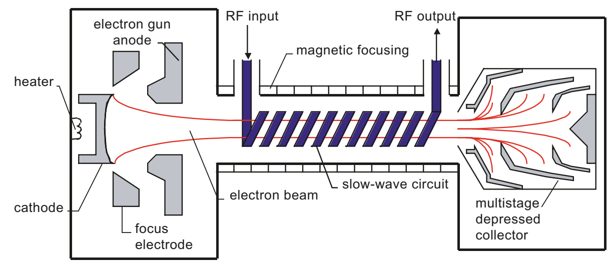

The Ka-band, 100W high-power traveling wave tube (left) operates as shown on right.

channels the electrons into a narrow beam, and the second electrode accelerates them into the delay line.

The delay line

The delay line consists of an electron beam focusing system and a helix coil, also called a slow-wave circuit. The focusing system consists of magnets that keep the electrons in a straight line as they pass through the axis of the helix and into the collector.

An RF signal is introduced into the helix, where it is amplified by kinetic energy from the electron beam, and is then transmitted to the antenna via wave-guide connections.

The collector

The collector consists of several electrodes that, in stages, slow down the electrons after they have amplified the RF signal, distribute them onto the collection surfaces, and recover them after impact. This reduces the final kinetic energy of the collected electrons, returning the unused energy to the electronic power conditioner (EPC) for improved efficiency. The remaining energy is dissipated as heat that is conducted into the TWT baseplate. The multistage depressed collector (MDC) on the 100W TWT enables overall efficiency near 60%.

Computer modeling

A well-calibrated computer model greatly reduces the hardware development time by replacing the iterative design-build-redesign-rebuild cycle with a single design-build cycle. Under the direction of project lead Richard Krawczyk at NASA's Glenn Research Center, the 100W TWT was designed and developed by Boeing Electron Dynamic Devices, Inc., on a computer using slow-wave circuit and collector design techniques. These techniques were pioneered by Glenn Research Center and are now widely used in the U.S. TWT industry. Specialists for each portion of the TWT, from electron gun to collector, refined the computer model, and then ran the code for design trade-offs, optimization and performance predictions. The validity of the model was demonstrated by the successful performance of the first 100W TWT device produced.

How the TWT will be used

The SC Project's TWT technology is one of the most critical elements of the high-rate microwave communications subsystem for deep space missions.

Krawczyk says, "The TWT on the Cassini satellite, currently on its way to Saturn, provides 10W output. The 2005 Mars Reconnaissance Orbiter will include a 35W TWT. Our new 100W TWT surpasses these in RF output, data transmission speed, and range of bandwidth. Although it's designed for 100W output, the flexibility of this design allows for tailoring the output nearly plus or minus 50% to fit power requirements for other missions while maintaining high efficiency."

The new 100W TWT will require the development of a new high-voltage EPC to convert the satellite bus power into the appropriate voltages and currents used by the TWT. Integrating the TWT and the EPC produces a Traveling Wave Tube Amplifier (TWTA), which could be qualified and ready with high-reliability flight hardware within two years, well in time for missions such as the 2009 U.S. Mars Telesat and others that follow.

The 100W TWT is another key technology being provided by the CICT Program's Space Communications Project for infusion into the emerging Space Internet.

–Larry Laufenberg

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